CO 1.0 Science and Technology – MRI will deliver high-quality scientific and technological outcomes that advance DOE priorities and Program objectives.

NREL Proposed Grade: Outstanding

PO 1.1 Demonstrate the quality of scientific and technological outcomes.

PI 1.1.1 Results of external and peer review validate the quality and impact of programmatic technical and/or analytical outcomes

PI 1.1.2 External recognition focused on NREL's technical and/or analytical work and outcomes: a) external awards and recognition; b) peer reviewed publications, and c) number of patents awarded.

Assessment Summary

NREL continues to produce high-quality science and technology. This is especially demonstrated by peer reviews and NREL's response to those reviews. During the last six months of FY03, NREL participated in six peer reviews involving the Photovoltaics subprogram; the Biomass program; the Hydrogen, Fuel Cells, and Infrastructure program; the FreedomCAR and Vehicles Technologies program; and the Wind and Hydropower Technologies program. It is also demonstrated by the external recognition that NREL has received. The Laboratory has, for example, won another R&D 100 Award for technological innovation. This is the fifteenth year in a row that NREL has won at least one of these prestigious awards, bringing the Lab's total to 35 since 1982; a remarkable number given NREL's size and the number of scientists and engineers it has in relation to other DOE National Laboratories.

	R&D 100	Peer Reviewed Publications	Patents Awarded
NREL Average per 100 Technical Staff* FY03	.30	66.77	5.4
NREL Average per 100 Technical Staff* FY02	.93	59.20	3.1
DOE Lab-System ** Average per 100 Technical Staff*FY93-FY02 Combined	.16	56.09	1.86
NREL Average per 100 Technical Staff* FY93-FY02 Combined	.71	67.41	5.24
*Technical Staff = Number of scientists and engineers **Labs used for benchmark:Ames, ANL, BNL, LANL, LBNL, LLNL, ORNL, PNNL, SNL			

NREL continues to demonstrate outstanding performance in these areas when compared to the benchmark of eight other laboratories.

Indicative of its vitality as an R&D institution, NREL was very active in publications, inventions, and patent activities. Out of the 1,116 publications produced by NREL staff, more than 900 were technical publications; and of these, 233 were peer-reviewed journal articles. The technical staff also submitted 60 records of invention, 22 U.S. patent applications, 26 foreign patent applications, and 12 PCT (patent cooperative treaty) applications; and was issued 14 U.S. patents and four foreign patents.

Highlights

Peer and Other Technical Reviews

Peer review, often cited as the most effective form of research assessment, provides an important evaluation of the relevance and quality of NREL research. NREL uses results of these reviews in planning future R&D and building technical capabilities.

- ***National Advisory Council Reviews Basic Energy Sciences.*** The Council reviewed NREL Basic Energy Sciences research. The Council noted the science is sound and world-class, and has the potential to contribute to energy challenges and opportunities. A distinguishing feature identified was that the basic theoretical and experimental research is well linked to the applied science and engineering at NREL.
- ***Wind & Hydropower Technologies Program Peer Review.*** A joint peer review meeting was held for the Wind and Hydropower Technologies Program. The meeting focused on strategic programmatic directions presented in the multi-year program plans, and on a high-level strategic review of ongoing RD&D activities. In addition to an independent peer-review panel, two industry associations American Wind Energy Association (AWEA) and National Hydropower Association (NHA) participated in the reviews and provided valuable feedback. The review

panels commended DOE and NREL for the excellent job they were doing managing the programs within the constraints of existing funding. Both the AWEA R&D committee and the peer review panel recommended that the Wind Program increase its emphasis on utility integration and wind resource measurements at the level of the new larger wind turbines (100+ meters). They also expressed their concern that the "cost of energy" was being used as a sole metric for measuring progress and performance. In response to this feedback, the Wind Program is enhancing its FY04 activities in the areas identified and is augmenting its "cost of energy" metric with other metrics within the Multi-year Program Plan.

- ***National Bioenergy Center (NBC) Peer Reviews.*** NBC hosted and conducted three peer reviews since April 2003. The areas of review were: Advanced Biomass Pretreatment Research, Enzyme Sugar Platform Research, and Syngas Platform Research. The Pretreatment and Enzyme Sugar Platform Research were conducted as interim stage reviews with more than 50 attendees representing DOE, USDA, industry, and academia, including many companies partnering with DOE and the national laboratories in CRADAs. The Syngas Platform Research Review encompassed seven projects, including all of PNNL's research, as part of the NBC, as well as most of NREL's Syngas R&D. Feedback from all three reviews was supportive of the research being done in the NBC. The first two reviews required very little adjustment to the Lab's research. The results and peer input from the review of the Syngas Platform Research are still being collected; but the review is expected to have significant impact on the direction of NREL's research.
- ***DOE PV Peer Review.*** The DOE PV Subprogram conducted a peer review of the Thin-Film PV Partnership and the PV Module and System Reliability activities. A DOE-selected panel reviewed 19 in-house and subcontracted projects, of both NREL and SNL. The initial feedback from the panel was positive; a full report is expected in early FY04, and will be used to guide FY04 research activities and priorities.
- ***Crystalline Silicon PV Subcontracts Peer Review.*** NREL conducted an in-depth peer review of seven university subcontracts supporting exploratory R&D in crystalline silicon areas identified by the U.S. PV industry. Based on 20-minute presentations and question-and-answer sessions, reviewers from BP Solar, SunPower, Evergreen Solar, Texas Instruments, RWE-Schott Solar, and a private sector crystalline silicon consultant identified strengths and weaknesses of the R&D. Suggestions resulting from this peer review will be used to redirect the next phase of research activities by the universities.
- ***Hydrogen, Fuel Cells and Infrastructure Technologies Program Peer Review***. DOE held its program review in May. Several NREL projects were reviewed on hydrogen production, storage, and fuel cells. All NREL projects were highly rated. As a result, the Lab will use the reviewers' comments to direct planning for the future of each project.
- ***USABC & FreedomCAR Technical Review.*** In May, July, and September, members of the U.S. Advanced Battery Consortium (USABC) and the FreedomCAR energy storage technical team reviewed NREL's technical progress on battery thermal analysis; a proposed thermal test procedure, a new calorimeter design; fuel-cell vehicle energy storage simulations; and battery modeling. The review team provided positive feedback on the relevance and quality of NREL's work. NREL is using the feedback to refine the thermal test procedure/calorimeter design and further define R&D projects for FY04.

External Recognition of NREL Technical Leadership

External recognition validates the quality, uniqueness, value, reputations, and contributions of Laboratory staff and NREL-produced science and technology. Examples of external recognition that the Laboratory received this period include:

- ***R&D 100 Award.*** NREL and First Solar, Inc. shared a 2003 R&D 100 Award for the development of "High-Rate Vapor Transport Deposition for CdTe PV Modules." This high-speed deposition technique enables in-line, continuous manufacture of efficient, low-cost, thin-film photovoltaic modules. It is the worlds first such mass-production method for making polycrystalline thin-film modules more than 10 times its nearest rival. This award brings NREL's total R&D 100 Awards to 35.

Vacuum chambers that house award winning high-rate vapor transport deposition system (HRVTD). The HRVTD can coat a 60 cm x 120 cm substrate with layers of CdTe and CdS semi-conductor material in 40 seconds.

- ***MacFarland Award.*** The Society for Automotive Engineers presented Wendy Clark with the

MacFarland Award, which is given to individuals in recognition of their contributions to industry over a sustained period.

- ***National Academy of Engineering Recognition.*** The National Academy of Engineering recognized Steve Slayzak as a leading young engineer for his work on liquid desiccant air-cleaning systems, and systems that can protect buildings from weaponized biological and chemical aerosol attacks.
- ***DOE Outstanding Mentor Award***. The DOE Office of Undergraduate Research Programs recognized Bonnie Hames and Kim Magrini-Bair for their dedication as mentors, sharing knowledge and inspiring and instilling confidence in the next generation of scientists and engineers.
- Cover Story Recognizes Value of Research. The Journal of Physical Chemistry recognized the value of research by Brian Gregg by highlighting his research on the cover of its May issue, and including his article "Excitonic Solar Cells, a New Mechanism Converting Sunlight into Electricity."
- In this research, the scientist proposed a new mechanism by which light is converted to electricity in organic semiconductors.
- ***Outstanding Young Scientist.*** Juki Yoshida, working on her Ph.D. research was recognized by the Third World Conference on Photovoltaic Energy Conversion as an "outstanding young scientist" for work performed on transparent conducting oxides for polycrystalline photovoltaics.
- ***EPA Award to NREL/DOE Building America Program.*** NREL received a 2003 ENERGY STAR for Homes Outstanding Achievement Award from EPA for providing technical leadership for the DOE Building America Program that resulted in the construction of more than 4000 ENERGY STAR homes last year.
- ***Best Paper Awards.*** Several NREL researchers received awards for best paper, including:
  - Two papers presented in different research categories at the Third World Conference in Photovoltaic Energy Conversion, held in Osaka, Japan.
  - A paper co-written by Ahmad Pesaran received the Vincent Bendix Automotive Electronics Engineering Award from the Society of Automotive Engineers (SAE). The award is given annually to recognize the best paper presented at all SAE meetings on the subject of automotive electronic engineering.

Elections and Appointments

David Renné was appointed associate editor for resource assessment of the Solar Energy Journal. This appointment recognizes the leadership NREL has attained through its support of the solar resource characterization project, which the scientist leads.

Helena Chum was appointed as a member to the Technical Advisory Committee to the California Integrated Waste Management Board, which assesses alternative pathways for biomass residues to energy, fuels, and other potential products.

Invited Leadership, Lectures, and Publications

Recognition of Laboratory staff by scientific and professional communities is indicative of the quality and importance of the work conducted by NREL to advance science and technology. Of particular importance are invitations to convey knowledge about renewables and energy efficiency to energy stakeholders outside the renewables community and to international audiences. NREL staff members received numerous invitations to write articles and to give talks that addressed a wide array of audiences and of renewable energy subjects. Among these were:

- A keynote address was given at the 2003 Glass Processing Days conference in Finland. The address, entitled "Stay Cool with Advanced Automotive Glazing," focused on air-conditioning fuel use and potential savings with advanced climate control techniques such as solar reflective glazings. As a result of the presentation, numerous companies inquired about working with NREL.
- Arthur Nozik presented "Carrier Dynamics in Semiconductor Quantum Dots and Potential Applications to High Efficiency Solar Photon Conversion," at the 203rd Meeting of the Electrochemical Society in Paris, France.
- Ahmad Pesaran presented his invited paper, "Energy Storage Systems Requirements for Fuel Cell Hybrid Vehicles" at the Advanced Automotive Battery Conference in Nice, France. This is a premier meeting on automotive batteries and it provides a forum for communication and coordination of work being conducted for DOE.
- David Ginley presented a plenary lecture at the 1st International Solar, Wind, and Hydrogen Meeting held in Spain.
- Several invited talks and plenary lectures were presented by NCPV staff members at the 3rd World Conference on Photovoltaic Energy Conversion in Osaka, Japan. This included a plenary presentation by

Tom Surek, "Progress in U.S. Photovoltaics: Looking Back 30 Years and Looking Ahead 20."

Conference Chairs and Organizers

Like invited lectures, being invited to organize and/or chair a major conference recognizes the national and international reputation of NREL researchers and organizations. During this period:

- The Materials Research Society (MRS) requested Rommel Noufi chair its 2003 fall meeting. This is a major recognition, as the prestigious event attracts several thousand attendees from all over the world. While NREL scientists have been quite active in the MRS for many years and have served as organizers for many of the symposia, this is the first time an NREL scientist was chosen to lead the conference. David Ginley was asked to chair the MRS conference for the fall meeting of 2005. Rarely has the Society turned to one organization for two leaders in such close succession.
- Tim Coutts and John Benner were invited to serve as chairs for the 31st IEEE Photovoltaic Specialist Conference, to be held in January 2005. John Benner and Lawrence Kazmerski were chosen to be on the International Advisory Committee for the 19th European Photovoltaic Science and Engineering Conference.
- David Ginley served as co-organizer of the conference on Transparent Conducting Oxide Thin-films for Electronics and Optics in Tokyo, Japan. Howard Branz was invited to co-organize the 22nd International Conference on Amorphous and Microcrystalline Semiconductors to be held in 2007.
- Michael Himmel chaired the Gordon Research Conference on Cellulases and Cellulosomes held in Hanover, New Hampshire. Gordon Research Conferences provide an international forum for the presentation and discussion of frontier research in the biological, chemical, and physical sciences, and their related technologies.
- Wendy Clark served as co-chair of the 2003 meeting of the Japan Society of Automotive Engineers/Society of Automotive Engineers International Fuels and Lubricants, held in Yokohama, Japan. Clark also presented the welcoming speech for this meeting. The meeting provides a forum for fuels and lubricants researchers from the United States, Asia, and Europe to discuss R&D issues.

Refereed Journal Articles and Intellectual Property

Two of the most important and historically recognized metrics for scientific achievement and technological progress are, respectively, refereed journal articles and patents. During FY03:

- NREL researchers wrote and published 233 peer-reviewed articles in a wide spectrum of highly respected journals.
- The Laboratory had an active year for intellectual property, culminating in 18 patents.

PO 1.2 Demonstrate excellence in program planning and management.

PI 1.2.1	Project management performance as measured against key milestones, budgets, subcontracting goals, and other commitments as negotiated and represented in approved AOPs.
PI 1.2.2	Program planning activities result in sound technical plans and well-developed longer-term program directions.
PI 1.2.3	Effective partnering and communication occurs between NREL and DOE program managers.

Assessment Summary

NREL executed its program roles through effective and agile program management that enabled meeting commitments and key milestones. The enhanced communications and closer working relationships between NREL and EERE programs noted in the first self assessment were continued and enhanced in the latter part of the year. This was most evident in NREL's significant involvement in providing technical leadership, strategic advice, and credible analyses to support the development of DOE multi-year technical plans and integrated annual operating plans. As a result, high-quality technical plans are emerging in each program and NREL efforts are aligned with the objectives of these plans. In several programs, such as the Biomass Program, NREL integrated efforts among laboratories, with industry, and among programs and addressed the recommendations from external reviews to ensure that individual efforts are aligned and mutually supportive of overall program goals. The enhanced role of NREL as a technical advisor and strategic partner in planning has yielded high-quality technical plans, such as the

multi-year RD&D plan for the Hydrogen, Fuel Cell, and Infrastructure Technologies Program, which was well-received by the National Research Council. NREL's analytical capabilities provided value to DOE planning by validating program technical targets, such as the preliminary system and component level targets for the heavy hybrid vehicles under the FreedomCAR and Vehicle Technologies Program and by bringing a systems perspective to program planning, such as in the Solar Technologies Program.

In executing its program responsibilities, NREL awarded $97M in subcontracts, 83% of these awarded on a competitive basis, thereby exceeding its annual goal of 70%. NREL's technical oversight of these subcontracts and the technical integration of subcontracted efforts with internal R&D continue to yield accomplishments that are advancing DOE's goals. NREL partnered effectively with the Golden Field Office to provide technical support to projects that are executed through the GO Project Management Office. NREL participated in the rollout presentation of the interim EERE corporate management system and began to plan how best to support its implementation in FY04.

The following examples highlight NREL's high standards and ongoing excellence in program planning and management.

Program Planning and Management Highlights

NREL supported DOE by serving as the technical integrator to develop multi-year RD&D plans and/or annual operating plans (AOPs) for the Biomass; Hydrogen, Fuel Cells and Infrastructure Technologies (HFCIT); Solar; and Wind Programs. In several cases, the technical support was facilitated by strategic assignment of staff to the NREL Washington, D.C. office.

- ***Draft HFCIT RD&D Plan Serves as Model.*** For the HFCIT Program, NREL provided technical support to establish the R&D agenda for the period FY04 - FY10 by recommending technical targets and milestones, designing technical approaches to overcome barriers, and designing and producing a draft multi-year RD&D plan for DOE. NREL also designed a change control process to manage the process of addressing comments on the plan.
- ***NREL Supports Development of First Integrated Solar Multi-Year Technical Plan.*** Working closely with Sandia, NREL played a significant role in the timely publication of the first-ever Multi-Year Technical Plan for the Solar Energy Technology Program. The plan projects goals to 2025, but focuses on the first five years of the technical programs and uses the system-driven approach to program management. Developing this plan was supported through assignment of technical staff in Washington, D.C.
- ***NREL Integrates Comprehensive Biomass MYTP Across Multiple Participants.*** NREL led the development of the MYTP and coordinated participation by GO, NETL, and all the labs in the NBC (NREL, ORNL, PNNL, INEEL and ANL). The plan includes work in feedstocks, the sugar platform, the thermochemical platform, products, and integrated biorefineries. It integrates decisions and plans developed as part of the ongoing stage gate management process and links technical work to the program's goals and strategies as spelled out in the MYPP.
- ***D.C. Support Enables Developing Wind & Hydropower Technologies Technical Plan.*** NREL provided technical support to the DOE Wind & Hydropower Technologies Program tailored to support DOE needs in multi-year program planning; annual program planning and execution; R&D portfolio evaluation and performance metrics; and the renewable energy title of the farm bill. Support was provided on technical analyses in critical areas such as offshore wind feasibility and wind produced hydrogen by electrolysis.
- ***NREL Leadership Supports Developing Key Subprograms Plans.*** In the FreedomCAR, Geothermal, Federal Energy Management Program, Weatherization and Intergovernmental, and Distributed Energy and Electricity Reliability Programs, NREL led the integration of key technical thrusts and/or participated actively in developing technical input to roadmaps and multi-year and annual plans. As examples:
  - NREL led efforts with DOE to organize and develop the Advanced Heavy Hybrid Propulsion Systems (AHHPS) R&D plan inputs to the Vehicle Systems R&D Plan. The R&D plan was integrated and coordinated with the 21st Century Truck Partnership (CTP) Heavy Hybrid "White Paper", including technical targets, barriers, and tasks, in an effort to keep Vehicle Systems research and development relevant to 21st CTP goals and objectives.
  - NREL worked closely with OWIP to prepare a five-year plan for the EERE International Program that

establishes strategic objectives and guiding principles, identifies core EERE international services, defines seven priority countries, and proposes six global and regional initiatives to be implemented FY04 through FY07.

- ***Web-Based Tools Facilitate Planning and Program Management.*** Several programs implemented new tools to facilitate planning and program management. For example, initial planning for the FY04 Solar Technologies Annual Operating Plan (AOP) was completed using a Web-based database system. This approach resulted in the earliest ever AOP draft for the program and enables DOE funding authorizations in early FY04. A limited-access intranet site was created for the NBC Laboratory Coordination Council to improve and maintain communications with DOE and all NBC labs.
- ***Major Solicitations Attract Quality Proposals.*** NREL conducted several major competitive solicitations during this period. As examples, two competitive PV solicitations, based on ongoing peer reviews to establish R&D priorities, together attracted 73 responses. The competition for "University R&D for Future Generation Solar Electric Technologies" attracted proposals from many of the top universities. Under the High Performance PV project solicitation, "14 proposals were selected for negotiations for award. The PV Manufacturing R&D project solicitation drew a higher response from the U.S. PV industry than was anticipated, representing a 30% increase in responses over the FY00 solicitation. In response to the solicitation for the "Minority University Research Associates Program," eight proposals were received from minority-serving institutions
- ***Technical Support Provided to DOE Solicitations.*** NREL provided technical support to several Golden Field Office (GO) solicitations. For example, NREL technical experts conducted reviews of nearly 70 Tribal Energy proposals supporting DOE selection of 16 awards to tribes totaling $2.9M. NREL continued to provide technical support to GO on two Wind Program research activities: the Field Verification Project for Small Wind Turbines (FVP) and Low Wind Speed Technology for Small Turbine Development Project (Small Turbine Project). In support of the Small Turbine Project, NREL provided technical assistance to GO on the pre-award process. The Small Turbine Project is an integral part of the Wind Program's Distributed Wind Turbine effort to help industry develop advanced technology that will allow distributed wind turbines to compete in lower wind speed sites in the United States for a wide variety of applications.
- ***Aggressive Steps Taken to Reduce Uncosted Balances.*** For example, NREL project managers worked diligently to reduce the carryover in the Photovoltaics subprogram from more than $17M at the end of FY02 to less than $8M (projected) at the end of FY03. In its FEMP efforts, NREL executed an aggressive plan to reduce uncosted balances from the FY02 level of $1.9M to an FY03 level of $1.1M. The continuing resolutions through the early part of FY03 made these accomplishments, and overall GSO management, even more significant.

Analytics Strengthen Program Planning

NREL was instrumental in strengthening the analytical foundation for program planning. In addition, NREL continued to work to integrate analytic efforts across programs. Example highlights include:

- ***Enhanced Vehicle System Technical Targets Tool Helps Establish Targets.*** The technical targets tool used to analyze DOE's FreedomCAR and Hydrogen, Fuel Cell, and Infrastructure program goals was enhanced to include a fully functioning graphical user interface, a design-of-experiments module for performing sensitivity analysis, and links to the distributed computing and optimization software NREL was using and improving. NREL completed a critical milestone to show preliminary system and component-level technical targets for heavy hybrid vehicles. The newly developed technical targets, where none had existed before, will help DOE and NREL establish critical R&D priorities and help direct the Advanced Heavy Hybrid Propulsion System (AHHPS) subcontracts toward critical technologies and heavy vehicle design approaches that satisfy program objectives of doubling heavy vehicle fuel economy.
- ***New Solar Model Enables Systems-Driven Approach.*** NREL and SNL worked together to develop a new Solar Analysis Modeling Program to enable a system-driven approach to program management.
- ***Comprehensive Study of Biomass Syngas Processes and Products Completed.*** NREL completed an important first step in identifying the most promising, cost effective fuel synthesis technologies where biomass thermochemical conversion could have a significant impact. Seven different syngas utilization processes and 14 products were evaluated. Fuel products included hydrogen, Fischer-Tropsch liquids, methanol, ethanol, dimethyl ether, and mixed alcohols. The report summarizes salient points regarding the processes and products considered including technology status and description,

chemistry, catalysts, reactors, syngas cleanliness requirements, process and environmental performance, and economics. The results of the analysis will help direct R&D efforts on selected products and processes with high likelihood of economic return and environmental benefits.

- ***Final Solar Diligence Report Completed.*** Under subcontract to NREL, Sargent & Lundy issued a final report on their due-diligence review of solar power tower and parabolic trough technologies. The conclusions provide a sound technical basis for R&D activities to lower the cost of CSP technologies and for providing continued analytical support for investigating the feasibility of deploying 1,000MW of CSP systems in the Southwest.
- ***Meetings Convened to Coordinate Analysis Across Programs.*** In addition to providing analytical support within individual programs, NREL convened several meetings to coordinate analysis efforts among programs and between TD and PBFA. For example, the first coordination meeting for hydrogen analysis was held with 17 organizations participating. NREL also hosted a Biomass Analysis Roundtable meeting in preparation of an OBP Multi-year Analysis Plan (MYAP). Attendees included analysts from OBP-HQ, all NBC labs, GO, and USDA.

Effective Partnering and Communicating

Increasingly, opportunities for advancing DOE's strategic goals are found at the interfaces among programs. NREL assisted EERE in defining these program interfaces. This resulted in a significant increase in interactions and collaborations between programs that yielded new opportunities or cooperative execution of related activities. In every program, NREL worked across the lab systems, with industries, and/or universities to enhance relationships that are key to planning and accomplishing program objectives. For example:

- ***Interfaces Between Hydrogen and Other Programs Defined.*** NREL assisted DOE in defining the hydrogen-biomass scope by proposing the identification of "mutual technologies of interest" to the two DOE programs. NREL provided a draft chart of collaborative hydrogen activities across DOE spanning hydrogen production through use in both stationary and transportation applications. NREL led a joint effort between the Hydrogen, Fuel Cells, and Infrastructure Technologies and Wind Programs to study the opportunities for producing hydrogen from wind.
- ***Distributed Energy Interfaces Managed.*** NREL maintained a well-integrated interface among the RD&D efforts that will remain in EERE and those that have transferred to the new DOE Office of Electric Transmission and Distribution (OETD). This ongoing focus on interfaces is important to leverage knowledge and capabilities effectively.
- ***Multi-Partner Collaboration Yields Strategy for Carbon Storage Research and Proposal for Virtual Center.*** NREL convened and chaired the Carbon Materials Working Group that identified potential RD&D strategies and laid the foundation for a proposed DOE virtual center on hydrogen storage on carbon-containing materials..
- ***National Collaborations Support Identifying Solar Technology Research Directions.*** NREL continued a highly successful series of national meetings in various solar technology areas, including CdTe, amorphous silicon, thin-film module reliability, and crystalline silicon, which are key to identifying future research directions and priorities.
- ***NREL Leadership Unites Nevada Organizations Around a Shared Plan.*** NREL worked closely with the Nevada Southwest Energy Project (NSWEP) board, comprised of representatives from the Nevada State Office of Energy (NSOE), Desert Research Institute, University of Nevada Las Vegas and University of Nevada Reno, to develop a unified voice to create and implement a plan for establishing Nevada as a recognized Southwest center of excellence in renewable energy research (including transmission and distribution infrastructure issues associated with renewable energy technologies).

PO 1.3 Produce S&T accomplishments that advance DOE and program objectives.

PI 1.3.1 Programs and projects produce significant research and development accomplishments that positively impact the advancement of DOE missions and program goals.

Assessment Summary

During the latter half of the year, NREL's science, technology, and analytical efforts yielded accomplishments that are moving DOE programs toward meeting their technical targets. These accomplishments include scientific and technological advances that result in reducing the cost or increasing the reliability of DOE-supported

technologies or that remove key barriers to their use. Key S&T accomplishments were made in every program, examples of which include demonstrating bench-scale production of hydrogen from waste plastic; significantly exceeding the target cost reduction for cellulose enzymes; completing long-term tests that show that diesel particle filters remain effective over time; receiving final approval of the distributed generation interconnection standards; validating the efficacy of liquid desiccant technology to deactivate anthrax spores using MRI's certified biosafety laboratories; increasing solar cell efficiencies; conducting independent tests of innovative NREL air-cooled condensers that show heat transfer coefficients are higher by as much as 80% than conventional designs; and advancing the understanding of nocturnal low-level jet streams in order to understand the potential impact on low wind speed turbine designs. Highlights of key accomplishments are summarized for each of the technology development programs below.

Biomass

- ***Genencor Exceeds Cost Reduction Target for Cellulase Technology.*** Genencor International (GCI) successfully completed its 3-year subcontract with NREL, exceeding the target of a 10-fold cellulase cost reduction by achieving an overall 11.1-fold cost reduction. The technical progress achieved by GCI will considerably enhance the likelihood that cellulase enzymes will be cost effective and available for the nascent bioindustry. Improvements made to the cellulase production process and to enzymes led to the significant overall improvement. During the subcontract, NREL worked closely with GCI evaluating new enzymes by testing them on real substrates, auditing production process improvements, and calculating cost reduction factors compared to the technology baseline using the bioethanol process model.
- ***Small Modular Biopower Systems Installed.*** Community Power Corporation (CPC) fabricated and completed field installation of three15-kW demonstration systems to SBS Wood Shavings in Ruidoso, New Mexico, American Forest Products in Zuni Pueblo, New Mexico, and Walden High School in Walden, Colorado. These field demonstrations constitute the final phase of a multi-year collaborative project by DOE, the U.S. Forest Service, and CPC. Goals for the field demonstrations include evaluating performance and correcting design flaws identified during long-term operation or in extreme operating environments. Following this demonstration phase the technology is expected to be ready for commercialization. The U.S Forest Service is interested in the technology as a productive use of forest thinnings resulting from forest fire mitigation activities.
- ***Successful Integrated Gasifer-Microturbine Operations.*** Extended microturbine operation on medium energy density fuel gases produced by gasifying biomass in the Thermochemical Process Development Unit (TCPDU) established the performance and exhaust emissions of the Capstone microturbine on hydrogen-rich fuels. As part of the effort to demonstrate the suitability of cleaned syngas for biorefinery utilities operations, the work was performed with the technical assistance of Capstone through a CRADA.
- ***High Sugar Yields Achieved at High Solids Loadings in Pilot Scale Pretreatment Reactor.*** Technoeconomic analysis indicates that solids loading in the pretreatment reactor have a major impact on the cost of producing sugars from biomass. For example, increasing solids loading from 20% to 30% results in reducing the cost of ethanol production by up to \$0.26¢/gallon. The technical target of greater than 30% solids loading in the Sunds pretreatment reactor was exceeded with 35% solids loading achieved. Sugar targets of 90% cellulose digestibility and 85% hemicellulose yield were met and exceeded respectively with conversion of 90% of the cellulose and xylan in the corn stover to monomeric and oligomeric sugars by the combined dilute acid and enzymatic cellulose hydrolysis processes at solids loadings near 30%. This extremely promising result suggests we are closer to achieving the technical targets required for a cost-effective process.
- ***Diffusion of Glucose at the Aqueous Boundary Layer of a Cellulose Microcrystallite Using Computational Chemistry.*** Computational simulations of "hydrolyzed glucose" at the cellulose microcrystallite boundary layer in water and the effects on the diffusion rate of glucose to the bulk medium have helped us understand why up to 65% of the potential released glucose is "lost" in some thermochemical hydrolysis reaction configurations. Bench scale experiments using polar solvents such as ethanol where completed which have shown that the presence of very dilute solutions of ethanol result in less unaccountable losses of glucose. Molecular modeling simulations, in conjunction with ongoing experimental efforts, suggest that glucose release from the cellulose surface involves significant perturbation energy which can be mitigated by the addition of polar solvents in a continuously flowing reactor system. The goal of the combination of

molecular modeling and bench scale experiments is to understand biomass carbohydrate hydrolysis mechanisms in aqueous systems, enabling improved biomass fractionation processes.

- ***Novozymes Demonstrates Lower Cost Cellulase Technology.*** Novozymes Biotech Incorporated made excellent progress and achieved the subcontract intermediate milestone goal of reducing the cost of commercial cellulases five-fold through reduction in processing and production costs. The milestone was met by two significant results: genetic modification of the cellulase production strain to express an important new component enzyme and addition of a new cellulase mixture that improves performance of the cellulase at elevated temperature by a further two-fold. The improvements resulted in reducing the required protein loading, yielding an overall 4.52-fold cost reduction. Combined with earlier process improvements, the five-fold cost reduction was achieved.
- ***Determined Structural Origin of Thermal Tolerance of Enzyme from Directed Evolution and Site Directed Mutagenesis.*** A map of the "hot spots" of T. fusca beta-glucosidase, where mutations led or can be expected to lead to increased thermal stability, was determined. A structural examination of the enzyme was based on computer modeling performed at NREL in collaboration with scientists at the University of Arkansas. Predictions of changes leading to thermal stability were generated and tested by site-directed mutagenesis. Success in these targets has laid the groundwork for FY04 efforts to determine whether this knowledge can be extended to engineering thermal tolerance into other enzymes in the same "family"; other family-1 glycosyl hydolases (GH). We expect this work to benefit industry in the near term by shortening the time required to develop new thermal tolerant family-1 (and perhaps other GH family) enzymes by protein engineering.

Building Technologies

- ***Building America Implementation of Technical Goals.*** NREL continued to work with the Building America (BA) teams to implement the new whole building integration R&D that can achieve 40-70% energy savings goals in new residences. The NREL-developed Building Optimization (BE-Opt) analysis tool is being used to evaluate least-cost system solutions at the 40%, 50% and 70% energy savings levels relative to the BA benchmark house as a function of housing type and climate zone.
- ***NREL Leads Development of Benchmark Research.*** Working in collaboration with Residential Energy Services Network (RESNET) and Pacific Northwest National Laboratory (PNNL), NREL has developed a research benchmark that will be used to evaluate progress toward residential building R&D goals. The benchmark includes a detailed description of all residential building loads including heating, cooling, lighting, hot water, appliances, and other plug loads.
- ***Habitat House Receives Highest E-Star Rating.*** NREL continued detailed energy performance monitoring of several Building America test houses as well as the Habitat for Humanity house sponsored by MRI and its integrated team of Battelle and Bechtel, and built by NREL and GO volunteers. As a result of several advanced energy efficiency features, solar hot water radiant heating, and a 1.5kW PV system, the Habitat house uses 79% less natural gas and 76% less electricity than a typical Colorado house of the same size. It received an E-Star rating of 95, the highest of any rated house in Colorado.


Habitat House

- ***Zero Energy Homes (ZEH) Optimization Analysis.*** NREL has used the BE-Opt analysis tool to determine the least-cost strategy to achieve Zero Energy homes in different climate zones. "An Optimization Methodology for Zero Net Energy Buildings" received the Best Paper Award for Solar Buildings and Conservation at the 2003 ASME International Solar Energy Conference in March.
- ***ZEH System Integration Procurement.*** Seven proposals were recommended for awards in response to the "Zero Energy Homes Energy Supply Systems Integration" solicitation that NREL issued and evaluated on a fast track schedule this period. The objective of this R&D solicitation was to initiate development of residential building-integrated products that incorporate the onsite generation of solar electric and solar thermal energy. Four of the contracts were awarded in FY03 with the remaining three awards subject to the availability of FY04 funding.
- ***Contractor Teams Complete Zero Energy Homes (ZEH).*** The ZEH contractor teams had two major accomplishments this period. The NAHB Research Center partnered with builder John Wesley Miller to complete a ZEH in the Armory Park del Sol development in Tucson, Arizona. The grand opening of the Clarum Homes 256 Zero Energy Home development in Watsonville, California took place in August.

- ***High Performance Buildings Case Studies Completed.*** NREL completed draft reports on design and detailed energy performance analysis of six major high-performance buildings. All of the buildings were 40% to 70% more energy efficient than code requirements and several had PV integrated electric generation and solar hot water. For five of these buildings, the Laboratory participated in the entire process, from building concept through design, construction, commissioning, and two years of performance data. NREL documented recommissioning and monitoring needed for the sixth building to help meet the original energy goals.
- ***NREL Leads New IEA Buildings Task.*** The IEA Solar Heating and Cooling committee selected Ron Judkoff as operating agent for the new Task 34/43 on building analysis software validation. These IEA tasks involve validation methods developed and field-tested by NREL and leading building R&D organizations around the world. They underpin ANSI/ASHRAE Standard 140, which addresses standard methods for testing and evaluating building energy analysis models.
- ***Innovative Electrochromic Window Coatings Evaluated.*** NREL has completed the first 10,000 cycles of testing for 35 prototype electrochromic devices supplied by Enki Technologies. The devices employ unique LANL-developed coating materials and were subjected to our small sample-screening test, which is designed to evaluate the degradation effects of various environments of light, cycling, and temperature.
- ***Energy-10 Software Development Effort Refocused.*** The ENERGY-10 development team concluded that it could not deliver Version 2.0 as originally intended within the current funding constraints due to unforeseen difficulty in modifying the ENERGY-10 legacy code so that it can implement multi-zone models and interact with newer software modules. Therefore, this task was refocused to deliver an update to the current two-zone version and to complete the SKETCH-10 user interface that allows rapid and intuitive description of building geometry and can provide an export file to EnergyPlus.

Distributed Energy and Electricity Reliability

- ***IEEE Interconnection Standard Clears Final Approval Hurdle.*** A key milestone was met when the IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems was approved by the IEEE Standards Board. The standard, which was published in early summer on a high-priority schedule, establishes the long awaited technical foundation to allow interconnection of all DG technologies to the electric grid. It also ensures that the return on federal and industry DG development investments will be realized. This standard will have a significant impact on how the energy industry does business in the future and will influence the way the electrical distribution system will operate with distributed generators and 2-way flow of electric energy.
- ***NREL Selected to Lead U.S. Participation in International Technical Committee.*** The Electricity Energy Supply Systems Technical Committee 8 (TC8) within the International Electrotechnical Commission's (IEC) scope is to prepare international standards or other deliverables necessary in an electricity open market to ensure the proper functioning of the electrical system considered as a whole, in coordination with other relevant Technical Committees. The IEC international standards support world trade; improve global industrial efficiency; provide the framework for economies of design, greater product and service quality, more interoperability, and better production and delivery efficiency; with all that leading to new markets and economic growth. Further, IEC conformity assessment and product certification schemes at the national level assure a certified product was manufactured and type-tested to well-established international standards. The end-user is assured the product meets quality standards and need not be concerned with further testing or evaluation of the product.
- ***Work on Standards that Complement 1547 Accelerated.*** Stakeholders identified a series of complementary IEEE 1547 standards needed on a fast track basis to effectively integrate DR technologies and to guide technology development for the grid of the future. On an accelerated schedule and accounting for tightening resources, virtual meetings were employed that significantly save travel expenses but increase coordination and planning efforts. NREL-hosted meetings to develop drafts of several IEEE interconnection standards: P1547.1 Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems; P1547.2 Application Guide for IEEE Standard 1547 for Interconnecting Distributed Resources with Electric Power Systems; and P1547.3 Guide for Monitoring, Information Exchange and Control of Distributed Resources Interconnected with Electric Power Systems.
- ***Islanding Testing of GE Universal Interconnection (UI) Device Conducted.*** NREL, GE Global R&D, and Multinlin conducted islanding tests at the NREL

DER Test Facility on a prototype Universal Interconnection UI device being developed under an NREL subcontract. The UI was tested with a synchronous generator and connected to the NREL utility grid simulator and islanding RLC load bank. The GE UI was designed to use only passive anti-islanding schemes and testing showed that there is still a significant non-detect zone with this type of anti-islanding protection.

NREL Installs GE UI Equipment
At DER Test Facility

- ***Command and Control for Distributed Generation Systems Evolved.*** NREL subcontractor RealEnergy completed a report that describes their evolving command and control system. The report includes data on information and communications requirements, development of the command and control algorithms for optimal dispatch, development of codes and modules for optimal dispatch algorithms, testing the codes using simulated data, installing and testing the Energy Management Software, and dealing with contractual and regulatory issues.
- ***Distributed Energy Neural Network Integration System Developed.*** NREL subcontractor Orion Engineering Corporation made progress in developing a Distributed Energy Neural Network Integration System (DENNIS™) to aggregate a community of small, distributed generators into a larger virtual single generator capable of selling power or other services. The strategy of discretionary control action at the household level, spread across all controllers in the DENNIS™ territory, enables the aggregated community to present a flat load profile to the utility. Orion has developed and validated the Control Law Generator, which demonstrated the ability to extract more savings from a DG system than basic control strategies and using the predictive abilities of the neural network. Using a very limited data set from only a month of weather data, the networks managed to achieve 80% accuracy in classifying the day type based on inputs of insolation, temperature, barometric pressure, and time of day. Orion also reported that preliminary benchmarking studies showed that the DENNIS™ system significantly outperforms net metering and avoided cost in compensating residential DG customers for generated power.
- ***Distributed Utility Integration Testing Program Developed.*** A report prepared by Distributed Utility Associates describes a proposed test of the electrical implications of deep and diverse penetration of distributed energy resources (DER) into distribution systems. As distributed power becomes more commonplace, its electrical interactions become more important and more challenging to manage. This testing program attempts to anticipate electrical interactions and discover the problems and benefits that will result from the extensive use of DER. This report provides a good overview of DER and issues with high levels of penetration.
- ***Distributed and Electric Power System Aggregation Model and Field Configuration Equivalency Validation Testing.*** NREL subcontractor DTE completed a report on a study to determine the magnitude of distributed resources that can be added to a distribution circuit without causing undesirable voltage regulation, power quality, stability, or reliability conditions or equipment damage. This research into the interaction between DG and distribution lines is one example of the ongoing efforts to develop the data and analytical tools necessary to assess the reliability and performance of the transmission and distribution system, and promote the deployment of new transmission and distribution system technologies. The detailed modeling, simulations, and analyses presented in this report provide repeatable methods and procedures to evaluate the effects of DG as well as quantitative conclusions and recommendations concerning DG penetration limits and protection equipment requirements.
- ***Coated Superconductor Successfully Prepared.*** A Bi-2122 coated conductor prepared from electrodeposited precursors showed current density of 5 x 106 A/cm2 at 4.2 K. The film quality was studied by TEM which showed phase pure Bi-2212 with minimal defect densities. Two papers were published: 1. R. N. Bhattacharya, J. Chen, R. D. Blaugher, "Biaxially textured superconductor Bi-oxide films via an electrodeposition process," IEEE Trans. of Applied Superconductivity, volume 13, number 2, page 2496, June 2003. 2. R. D. Blaugher, R. N. Bhattacharya, and J. Chen, "Bi-2212: An HTS coated conductor," IEEE Trans. of Applied Superconductivity, volume 13, number 2, page 3343, June 2003.
- ***Testing of Liquid Desiccant Deactivation of Anthrax Spores Completed.*** MRI completed testing of spore deactivation at their BioSafety Level 2 and 3 labs.

Validation of NREL kill results and extension to actual Anthrax increases credibility of our findings of 99.99% bacillus spore kill. MRI anthrax results show accelerated Anthrax spore kill using liquid desiccant. MRI also completed analysis on electrostatic collection enhancement for sub-micron (spore-sized) particles. The literature and MRI experience indicate that ESP can be used with NREL's regenerable core technology to increase spore capture to HEPA filter levels of 99.97% and higher. The capture analysis provides NREL with an experimental ESP design it can implement in the lab and use to establish HEPA-level air filtration capabilities for our new liquid desiccant air conditioner.

- ***Initial Evaluation of Enabling Technologies Completed.*** Initial evaluation of an enthalpy exchange membrane indicates that it offers a 3-fold increase in moisture recovery relative to state-of-the-art fixed core enthalpy exchangers, making it comparable to rotating devices while eliminating moving parts. This reduces costs and maintenance and opens markets with drop-in applicability. These energy-saving capabilities are useful in buildings and are of particular interest to the PEM fuel cell industry for stack moisture management. Evaluation of a staged indirect evaporative cooler concept shows it is an excellent heat rejection complement to desiccant cooling. It can cool air below its wet bulb temperature, effectively doubling state-of-the-art capacity; this performance is unaffected by the high temperatures exiting the drying stage, making possible non-compressive total cooling systems with Seasonal Energy Efficiency Ratios over 20.

FreedomCAR and Vehicle Technologies

- ***Safety and Performance Assessment of E-diesel Completed.*** A study assessing the potential failure modes for vehicles operating on ethanol diesel blends (e-diesel) was completed. Notably, the analysis did not reveal any unanticipated issues. The potential for fuel tank ignition and vapor lock were the highest risks, and low to moderate costs solutions were proposed that reduce risks to levels similar to that encountered in using gasoline. The study confirms the potential of this fuel for practical use in centrally refueled fleets and contributes towards attaining DOE's petroleum displacement goals.

Destructive testing of e-diesel fuel tank without flame arrestor

- ***Fuel Cell System Modeling Capability Expanded.*** Significant improvements were made to ADVISOR™ fuel cell models. The vehicle speed has been linked to the heat transfer processes in the radiator and the condenser, and the fuel cell model equations were updated to include inlet ambient pressure as a variable. These improvements are significant because they allow the tool to analyze the impact of altitude and ambient temperature on fuel cell vehicle performance and fuel economy. This also relates to one of DOE's key technical barriers for fuel cells, which is thermal and water management.
- ***Energy Storage Options for Improving Fuel Cell Vehicle Efficiency Investigated.*** NREL evaluated the benefits and requirements of energy storage (batteries or ultracapacitors) for fuel cell hybrid vehicles using ADVISOR™. Analyses indicate that batteries or ultracapacitors could capture significant regenerative braking energy, which enhances the fuel economy of fuel cell vehicles. Component operating characteristics on an acceleration test compared favorably with those published on Honda's FCX vehicle. Preliminary results were presented to the Fuel Cell, and Energy Storage FreedomCAR technical teams. Industry representatives were pleased with the results and requested more results on component sizing, control strategy, and fuel economy benefits of ultracapacitors in fuel cell hybrid vehicles at the next meeting.
- ***Six Sigma Design Applied to Hybrid Vehicle Battery Thermal Management.*** NREL worked with the FreedomCAR energy storage technical team and Ford to apply six sigma design techniques to improve the thermal management of batteries for hybrid vehicles. Six-sigma design is the latest trend in the automotive industry for improving quality and robustness of products. It combines NREL's NiMH battery experience with computer-aided design tools and six-sigma design. Results from this analysis were discussed in a September meeting at Ford with the FreedomCAR energy storage technical team. The results will help FreedomCAR developers choose the best battery approach for their next generation HEVs.
- ***Team Develops Thermal Test Procedure for Benchmarking Batteries.*** NREL supported FreedomCAR Energy Storage to establish a standard for testing and benchmarking a battery thermal

management system for hybrid applications. NREL proposed a test procedure backed by experiments of Saft 48-Volt air-cooled and liquid-cooled modules. In September, the FreedomCAR Energy Storage technical team reviewed the proposed test procedure and provided feedback on finalizing it.

- ***Optimum Parameters for Battery Preheating Studied.*** To overcome the poor performance of hybrid vehicle batteries in cold climates, NREL assembled an experimental setup consisting of an alternating current (AC) amplifier, a battery cycler, an environmental chamber, and electronic interface. Tests were conducted at –30ºC for a prismatic NiMH battery. Parameters were studied for the eventual design of an on-board heater to overcome the cold cranking technical barrier.
- ***Study Presents Major Findings on Weekend and Weekday Differences in Ozone Levels.*** NREL co-authored several technical and summary papers in the Journal of the Air & Waste Management Association concerning results from a weekend ozone effects study in California's South Coast Air Basin (Los Angeles area). The study indicated that despite large reductions of hydrocarbons and nitrogen oxide emissions on weekends, weekend ozone levels are nearly identical to or higher than weekday ozone levels in many urban locations in the United States.

- ***Tests Show that Diesel Particle Filters Remain Effective Over Time.*** NREL tests of the Ralph's Grocery fleet indicate that diesel particle filters installed in 1999 continue to show emission reductions after four years of operation. The Ralph's project was designed to test 15 diesel-fueled delivery trucks using emission control diesel and diesel particle filters. Now, after almost four years of operation and more than 450,000 miles, the filters continue to show significant reductions in emissions.

- ***Study Shows Canadian Tar Sands Diesels Have Equivalent Emissions Performance.*** NREL completed a study showing that diesel derived from Canadian tar sands has properties such as emissions of nitrogen oxides and particulate matter that are identical to conventional diesel. The results support continued importation of tar sands crude and diesel from Canada into the United States, which may affect imports from other countries.
- ***Fischer-Tropsch Performance Exceed Goals.*** As part of a CRADA with the South Coast Air Quality Management District, NREL tested two identical 2002 Cummins engines equipped with exhaust gas recirculation technology and optimized for use with Fischer-Tropsch (F-T) fuel. Both engines met or exceeded project goals for emissions. The engines were tested using the Federal Test Procedure and resulted in reductions over the standards for NOx and PM. The engines also exceeded targets for NO2. NOx emissions were reduced by 15% with F-T compared to California diesel fuel. These tests show that the NOx reduction with F-T does not depend on engine age and technology. The project is a cost-shared collaboration with California regulatory agencies, Cummins Engine Company, and Shell.

Photo of a Cummins engine being tested

- ***Report Shows Benefits of Hydrogen-Natural Gas Fuel Mixture.*** NREL produced a milestone report that details the status of a project to develop and demonstrate hydrogen-compressed natural gas (HCNG) blend transit buses. Compared with a compressed natural gas (CNG)-fueled engine, the HCNG-fueled engine reduced emissions of nitrogen oxides (NOx) by 50%, non-methane hydrocarbons by 58%, methane by 16%, and total hydrocarbons by 23%. This was accomplished with no significant change in fuel efficiency between the HCNG- and CNG-fueled engines. The HCNG-fueled engine also maintained transient speed and torque capability. These results could be significant in defining a path from conventional transportation fuels to the new hydrogen economy.
- ***The ADvanced Automotive Manikin (A.D.A.M.) Gets a Brain and a Say in Thermal Comfort.*** The thermal comfort manikin, containing 126 individually controlled heated and sweating segments, can now be controlled by the numerical model of the human thermoregulatory physiological system. The complex finite element model receives heat fluxes from each of the 126 segments and calculates the resulting skin temperatures and sweat rates which are sent to the manikin. The model includes thermal conductivity, thermal capacitance, and heat generation for each element in the body. A network of pipes to simulate the human circulatory system models convection heat

transfer. Breathing is also modeled. The physiological model sends local skin temperatures to the psychological model that calculates local and global sensation and predicts local and global comfort.

- ***Thermal/Fluid Analysis Capabilities Support a Key Power Electronics Vendor.*** NREL used its thermal/fluid analysis capabilities to develop a more optimized heat exchanger package for a key power electronics inverter designed and built by Semikron. Semikron will adopt the new optimal design techniques suggested by NREL in their next generation inverter products. The more optimal heat exchanger opens the door for lightweight, compact inverter designs in advanced hybrid electric and fuel cell vehicles.
- ***Unique Class 4-6 Drive Cycle for Evaluating Heavy Hybrid Vehicle Performance Developed.*** NREL worked closely with Eaton Corporation and International Truck and Engine to develop a new, unique drive cycle (Composite International Local and Commuter Cycle) to accurately and cost-effectively evaluate Class 4-6 heavy hybrid vehicle performance benefits. This new drive cycle represents a new industry standard to judge Class 4-6 heavy hybrid performance and will be presented at both the SAE 2003 International Truck and Bus Meeting & Exhibition and in an official publication at the SAE 2004 World Congress.
- ***Development of Next-Generation Hybrid Electric Transit Bus Initiated.*** NREL initiated a project with GM Allison to develop the next generation electric drive unit and power electronics in the Allison EP system. The $5M, 32-month project will improve the system efficiency to result in a targeted 100% increase in fuel economy over a traditional diesel powered transit bus application. A kick-off meeting was held in June at the Allison Facility and a Program Implementation Plan meeting was held in July at DOE in Washington, D.C. A definitized subcontract was completed in September.
- ***Heavy-Duty Natural Gas Engine Approaches EPA 2010 Emissions Standards.*** The DOE/NREL Next Generation Natural Gas Vehicle activity supported development of a 12-liter Caterpillar engine with Clean Air Partners natural gas technology. The engine demonstrated oxides of nitrogen emissions of 0.5 g/hp-h and particulate matter emissions (PM) of 0.004 g/hp-h. By 2010, EPA will require NOxemission of 0.2 g/hp-h or less and PM emissions of 0.01 g/hp-h or less. The technology demonstrated in this project will help natural gas engine manufacturers meet these requirements.

Geothermal Technologies

- ***Ammonia-Water Condensation Experiments Completed and Data Transferred.*** There was a substantial effort to complete the ammonia-water condensation experiments with the data transferred to Heat Transfer Research Inc. (HTRI) for inclusion in their design codes. The most recent data transferred to HTRI is the process side heat transfer correlation for ammonia/water condensation at various inlet vapor concentrations.
- ***Technical Support Provided to GeoPowering the West.*** NREL provided significant input to the GeoPowering the West effort, including planning and support to organize and implement the National Geothermal Collaborative (NGC). NREL participated in a May meeting at the U.S. Forest Service (USFS) in Washington, D.C., on assessing renewable resources on forestlands. NREL identified leasing of geothermal resources on USFS lands as a barrier to be addressed by the NGC.
- ***NREL Supported IEA Direct Use Annex.*** NREL provides DOE-HQ support for International Energy Agency Geothermal Implementing Agreement activities by operating a common fund for 10 countries. A draft charter was developed by NREL for the Direct Use Annex.
- ***Research Advances Coatings Technology.*** NREL expanded PPS coating testing to other sites and more rigorous conditions. The first test of 40 foot-long tubes internally coated with PPS was started at Mammoth with exposure to production brine in June. That size tube is typically used at binary power plants and the ability to make a defect-free coating the entire length must be confirmed. PPS-coated steam vent pipelines at the Cove Fort plant showed no sign of attack from acidic condensing steam after 14 months of service. Tests of coated and uncoated tubes started at Puna in August. This is the first time tests were done at Puna, a high-temperature resource.A brine spray test of OMP-coated aluminum-finned steel tubing was started at Mammoth. This is the first test of the new OMP coating in exposure to brine spray. Tests of PPS-coated carbon steel pipe spools were started at a CalEnergy facility in the Salton Sea KGRA. The use of PPS-coated carbon steel well field pipe instead of problematic concrete-lined pipe could lead to major savings.
- ***Innovative Heat Transfer Concepts Improve Efficiency.*** NREL continued work on innovative heat transfer concepts, with transpired fins and with tabbed fins as well as with the fin-on-plate heat air-cooled condenser. The concepts are expanding the envelope of air-cooled condensation technology.

NREL completed and tested a modified fin-on-plate heat exchanger with a new vapor distribution system as well as two new sets of fins. Laboratory tests show that heat transfer coefficients are higher by as much as 80% (at higher velocities) compared to tube and fin configuration. Because of higher heat transfer coefficients, the surface area required is much smaller, therefore reducing the ground coverage by as much as 30%. NREL researchers have filed for a provisional patent on this new component. Three papers on the performance of this unit with steam, and ammonia/water mixtures were published. NREL researchers arranged for independent testing of the fin-on-plate heat exchanger by Intertek Testing Systems (ITS). The results of ITS tests compare very well with those of NREL. They are within 10% of each other.

- ***Tool Designed to Make Tabbed Fins.*** A tool was designed and fabricated for punching individual tabs into fin surfaces. Two small three-row test articles were prepared – five fins per inch and 10 fins per inch – and tested in NREL's transient test loop. Results showed ratios of heat transfer enhancement to pressure drop increase that is superior to louvered and wavy fins used by our industry partner, Super Radiator Coils. A provisional patent application for tabbed fin enhancements was submitted.
- ***Analysis of 1MW Plant Improves Design.*** NREL completed an analysis of a trim condenser and determined an optimum size for a proposed 1MW plant at Empire, Nevada. The analysis indicated that such a design would be marginally cost-effective, and NREL identified two ways to improve its performance: use of a mixed working fluid and use of an evaporative condenser. Results of an analysis indicated that a mixed working fluid could provide a significant reduction in the cost of delivered energy. NREL worked with Empire Energy and DOE to resolve final issues regarding continuance of the Empire design and prepared a contract modification that covers revision of the preliminary design and completion of a final design that utilizes a mixed hydrocarbon working fluid.

Hydrogen, Fuel Cells, and Infrastructure Technologies

- ***Reversible Inhibition of CO-Shift Process Studied.*** The biologically mediated water-gas shift reaction may be a cost-effective alternative to conventional technology for the conditioning of synthesis gas streams to produce additional hydrogen. The bioreactor must be operated at elevated pressures to achieve favorable process economics, but previous NREL results indicate that when the bioreactors are operated at elevated pressures, a reversible inhibition of the CO-shift process occurs. NREL developed a novel bioreactor design, the recirculating bubble column, and determined the causes of the inhibition. These results led to NREL's recommendation to conclude work on this pathway to hydrogen production.
- ***Photobiological Hydrogen Production Advanced***. Hydrogen-producing algae coproduce oxygen, which inhibits the hydrogen-producing enzyme. NREL showed that this oxygen inactivation can be limited by preventing oxygen accessibility through genetic engineering of the hydrogen-channel. By inserting a tryptophan side-chain, a physical barrier, or shield, is created that reduces the rate of oxygen diffusion into the active site. NREL designed a new system for continuous photo biological production of hydrogen by algae. Ten days of continuous production were demonstrated under sulfur-deprived conditions, more than doubling the production time of batch reactors.
- ***Understanding of Genes Enables H_2 Production***. NREL identified two additional genes involved in the water-gas shift (WGS) pathway in Rubrivivax gelatinosus CBS. Eleven of the 15 genes that are involved in WGS were completely sequenced at NREL. NREL demonstrated the ability to insert WGS genes of its choosing into CBS cells to make more of the H_2-production related proteins.
- ***Bench-Scale Production of H_2 from Waste Plastic.*** NREL demonstrated the production of hydrogen from complex waste plastics at the bench scale. Pyrolysis of polypropylene and catalytic steam reforming of the resulting volatiles over 10 hours produced hydrogen at 80 percent of stoichiometric conditions.
- ***Technologies For Producing Hydrogen From Biomass Advanced.*** NREL successfully tested a new support material for catalysts that resists: 1) attrition in a fluidized bed; 2) coking on the catalyst; and 3) formation of deposits at the point of injection of the biomass feedstock into the process. This allows gasification or pyrolysis of biomass to be extended for a significant period compared to previous technologies.
- ***Sustainability of Semiconducting Nitride Materials as Photoelectrochemical Water Splitting Devices Assessed.*** Two materials, InGaN and GaPN, showed high stabilities, and all of the InGaN samples had the appropriate band edge potentials to split water into hydrogen and oxygen in acidic solutions. NREL determined that either of these materials has the possibility of reaching the DOE near-term 2005 goal of 7.5% efficiency and 1,000-hour lifetime.

- ***Pressure Swing Adsorption Systems Evaluated***. In support of the Clark Atlanta University Biomass to Hydrogen project, NREL evaluated Pressure Swing Adsorption (PSA) systems for applicability to the biomass to hydrogen technology. Using the product vapor composition from the NREL tests and the 100-hour run in Georgia, NREL provided detailed specifications to Clark Atlanta and their partner, Eprida, for procurement of a PSA unit to be installed at the facility in Georgia.
- ***Conceptual Design of Bubbling Bed Reactor Completed.*** NREL completed the conceptual design for a 10x scale-up of the bubbling bed catalytic steam reforming reactor to 250-kg hydrogen per day capacity. This design will facilitate construction of a pilot-scale biomass to hydrogen system with better heat integration towards achieving the goal of 87% reforming efficiency.
- ***Hydrogen Storage Science and Technology Advanced***. NREL synthesized metal-tipped, multi-walled, carbon nanotubes by hot-wire chemical vapor deposition. Hydrogen uptake was increased due to carbon/metal synergy. NREL's theoretical calculations of hydrogen binding on boron substituted C_{60} showed an elongated H_2 bond length characteristic of non-classical hydrogen binding. This helps to explain enhanced storage of hydrogen. NREL scientists developed new calibration techniques for temperature programmed desorption apparatus that will enable rapid throughput measurements. NREL researchers implemented a fluorescence technique that enables the tube types in heterogeneous single-wall nanotube samples to be identified.

Senior scientist Mike Heben peers into desorption apparatus used to measure hydrogen storage properties of carbon materials.

- ***Modeling Results Correlated with Fuel Cell Experiments.*** NREL computer-aided engineering modeling results correlate with Plug Power experiments for fuel cell components, including stress and deflection in membranes for three fuel cell stack designs for stationary fuel cells and autothermal reformer – fluid flow.
- ***First Evaluation of a Prototype Fuel Cell Transit Bus Completed.*** NREL completed the first evaluation of a prototype fuel cell transit bus utilizing proton exchange membrane (PEM) fuel cells. The bus met or exceeded all of the goals set for the six-month demonstration. The results of this limited evaluation show a fuel cell hybrid propulsion system is capable of performing well in transit service.
- ***Critical Code Items Addressed.*** NREL hosted a meeting of the International Code Council's (ICC) Hydrogen ad hoc Committee in May to discuss and prepare proposed amendments to the ICC's 2006 code revision cycle. Several key items were included in the next set of proposed amendments that were discussed at the ICC public hearing in September. These items include provisions for underground storage of liquid hydrogen and storage of compressed gaseous hydrogen above fueling dispenser canopies. Both provisions are critical for hydrogen fueling infrastructure development.

Solar Energy Technology

- ***New Concentrator Cell Record Achieved.*** Spectrolab Inc., under a cost-shared NREL subcontract, continued remarkable progress in conversion efficiency records for a terrestrial concentrator solar cell. Previously, Spectrolab improved the efficiency from 34% to 35.2% under concentrated sunlight. This period, Spectrolab achieved 36.9% efficiency for a triple-junction structure, another significant improvement. This result builds on the NREL-patented two-junction device licensed by Spectrolab. In a related development in the High Performance PV project, NREL researchers identified a "signature" for the primary problem with GaInNAs, under investigation as a possible third junction in a four-junction device aimed at achieving 40% efficiency. The defect causes short minority-carrier lifetime in the material. This is a major step in developing techniques to eliminate this defect.
- ***NREL Leads in Application of Combinatorial Materials Science.*** This novel approach for high throughput research allows families of materials and combinations of materials needed for device structures to be rapidly explored. NREL completed experiments creating thousands of different compositions of dielectric films during this six-month period. Also, the combinatorial growth of a library of silicon thin-film samples helped to quickly "home-in" on optimum conditions for the material. NREL's leadership in this field is recognized by

invitations to lead conferences and symposia, such as the upcoming MRS conference.

- ***Progress in Thin-Film Tandem Cells.*** NREL demonstrated a prototype tandem using Si and CuGaSe2 (CGS) as the bottom and top cell absorbers, respectively. The CGS top cell was grown by elemental evaporation following the NREL-patented three-stage process. The interconnect junction consisted of an n+-ITO. Initial measurement showed excellent voltage addition of about 1.3 V, and efficiency of about 5.1%. NREL subcontractor, the Institute of Energy Conversion at the University of Delaware, developed a potential wide-bandgap cell based on Cu(In, Ga)(Se, S)2, with the best performance obtained for low S and high Ga contents. Cells were tested with an AR coating at NREL and were more than 10% efficient, meeting an important milestone for the High Performance PV project.
- ***Basic Science Research Advances Forefront of PV Technology.*** NREL, working with Rutgers University, reported unusual electronic properties of novel one-dimensional, two-dimensional, and three-dimensional inorganic-organic semiconductor networks with great potential for applications in areas of photovoltaic and solid-state lighting. A novel hybrid organic-inorganic (AnTe/Tetracene) superlattice structure was found to have properties that include a very strong quantum confinement shift that will be useful for novel solar cells and LED devices. NREL also found experimental evidence suggesting that dye-sensitized solar cell performance cannot be significantly improved by enhancing the electron transport rate. Before this study, there was considerable effort to improve the efficiency of dye solar cells based on the perception that speeding up electron transport would reduce the rate of recombination. Finally, computational materials research studies showed that n-type doping in CdZnTe, an important PV material, can be significantly enhanced as a consequence of mutual repulsion of two donor levels in the material.
- ***Progress in PV Manufacturing R&D.*** Several NREL subcontractors reported major technical progress in their manufacturing R&D projects. Energy Photovoltaics achieved a 10% gain in stabilized power output and a 30% reduction in direct manufacturing costs. ITN Energy Systems in collaboration with Global Solar Energy completed several modeling tasks supporting the advancement of CIGS module production. They developed physics-based and empirical models for deposition processing, implemented model-based control for CIGS processing, developed in-situ sensors, and applied predictive models to the construction of new evaporation sources for CIGS production deposition processes. Energy Conversion Devices completed an investigation of both chemical and plasma substrate cleaning processes resulting in an improvement in their production yield. They also developed closed-loop thickness control systems for the deposition of their ZnO, ITO, and a-Si component layers, as well as a PV Capacitive Diagnostic (PVCD) system for the measurement of the J/V characteristics of component cells in the triple-junction device. These in-line, real-time QA/QC tools are expected to make significant improvements when implemented at the Uni-Solar 30MW/yr manufacturing facility in Auburn Hills, Michigan. Finally, Specialized Technology Resources worked with BP Solar, Shell Solar, and Energy Photovoltaics in developing alternative, low-cost encapsulants for specific module types and end-use applications.
- ***Improved Concentrating PV Module Successfully Tested.*** Several Spectrolab concentrating photovoltaic (CPV) modules were tested at the NREL High Flux Solar Furnace (HFSF). Efficiencies (based on cell area and incident flux at the module plane) slightly over 30% were obtained, very close to test results at ideal laboratory conditions for a single cell. With further development in this area, Spectrolab will be in an excellent position to provide cells for CPV receivers. Spectrolab is interested in working under a CRADA agreement with NREL and Solar Systems Ltd. to develop cells for near-term dish applications.
- ***Optical Testing of Mirror Panels.*** NREL continued to provide optical characterization assistance to the CSP dish industry using our unique Video Scanning Hartmann Optical Test (VSHOT) system. This assistance included testing of dozens of Science Application International Corporation (SAIC) fixed focal length mirrored facets intended for use with Stirling or concentrating PV receivers as well as Stirling Energy System's (SES) facet design (produced by Paneltec Corporation) intended for use with their 25kW Stirling systems.
- ***PV System Testing Standard Approved.*** The IEEE-SA Standards Board Review Committee approved IEEE P1526, "Recommended Practice for Testing the Performance of Stand-Alone Photovoltaic Systems," as a new recommended practice. The new standard provides procedures that independent testing laboratories will use to evaluate the performance of stand-alone PV systems. In the United States FSEC was approved by Powermark Corporation to provide certification testing for PV systems, and plans on using P1526 to certify PV system performance. P1526 is also the basis for international standard, IEC 62124,

"Photovoltaic Stand-Alone Systems – Design Qualification and Type Approval." Work on P1526 was based on validation testing conducted on stand-alone PV systems at NREL, Sandia, SWTDI, and FSEC over the past five years.

Wind & Hydropower

- ***Lamar Low-Level Jet Project Yields Initial Results.*** NREL published a technical report, entitled The Lamar Low-Level Jet Project Interim Report, which presents the experimental results to date of a collaborative effort between DOE, NREL, and GE Wind Energy. The purpose of the project is to develop an understanding of the influence of nocturnal low-level jet streams on the inflow turbulence environment and to document any potential operating impacts on current large wind turbines and the Low Wind Speed Turbine designs of the future. A year's record of detailed turbulence measurements were collected from NREL instrumentation installed on the GE Wind 120-meter tower in southeast Colorado and supplemented with mean wind profile data collected using an acoustic wind profiler or SODAR. The FY02 Peer Review Panel identified this research activity as a high priority and felt that NREL should accelerate characterization of events like those caused by the nocturnal jet.

GE Wind 120 meter meteorological tower South of Lamar, Colorado

- ***Advanced Drive Train Testing Initiated***. NREL began testing three advanced drive trains optimized for low wind speed applications. The advanced drive trains that are being developed under Low Wind Speed Technology public/private partnerships will be tested at the NWTC 2.5MW Dynamometer test facility in FY03/04. Testing of the Clipper Windpower's 1.5MW distributed generator drive train (DGD-1) is underway at the NWTC and will continue into the fall. Innovative 1.5MW drive trains designed by Global Energy Concepts and Northern Power Systems are currently being built and are undergoing acceptance testing at the vendors' facilities and will be tested at the NWTC immediately following the Clipper test.
- ***Testing and Field Verification of Small Turbines.*** NREL published 13 test reports on three different small wind turbine models that are installed and operating at different sites throughout the United States. The small turbine tests, conducted at the NWTC, included power performance, noise, duration, and safety and function testing in accordance with domestic and international standards. NWTC test results are available for comparison against the manufacturer's specifications and performance data collected at the FVP sites.

Analytic Studies

- ***Distributed Power Technology Characterizations Completed.*** NREL led a collaborative effort to produce technology characterizations for six distributed power technologies. This consensus information on the current and projected performance and cost characteristics for these technologies is critical for both energy systems analysis and technology program planning purposes. The development of these characterizations is complete, and the results will be published and made available on the Internet.
- ***Analytical Support Provided for GPRA Projections.*** NREL prepared process guidance for EERE's development of GPRA projections for the FY2005 budget submission, and is working with EERE to develop the projections that are a key element of EERE's communication of the prospective benefits of its programs.
- ***Power Technologies Databook Updated.*** NREL completed an update of the Power Technologies Databook that provides current information on electricity sector resources, technologies and markets, and the EERE technologies and programs relevant to that sector. It is available at nrel.gov/analysis/power_databook/
- ***Distributed Energy Database Developed.*** NREL completed development of a Distributed Energy Resources database that merges information from other sources and provides a current, accurate summary of DER systems in place today.
- ***Renewable Power System Database Updated.*** NREL completed an update of the REPiS database on renewable power system projects to include information through 2002. This database is valued by DOE, EIA, and external stakeholders as being the most definitive source for information on grid-connected renewable energy systems.

PO 1.4 Effectively communicate and transfer NREL-developed knowledge and technology.

PI 1.4.1 Private sector partnerships have been developed for commercialization of NREL technologies.

PI 1.4.2 Meet or exceed established technology transfer metrics.

PI 1.4.3 Quality communications products are developed and recognized as supporting the advancement of Program goals.

Assessment Summary

MRI and its integrated team of Battelle and Bechtel continued to provide appropriate stewardship of DOE-sponsored, Laboratory-originated knowledge, technology, practices, tools, materials, and/or processes. This stewardship included managing knowledge from its creation through its transfer to other for their use. NREL-developed knowledge and know how was transferred through a record number of publications, through technical assistance to domestic government organizations and international organizations, and via a variety of partnerships with the commercial sector.

Through its role in the Federal Energy Management Program (FEMP), NREL transferred technical knowledge of renewables to support a record number of federal facility energy projects. NREL has enabled the government sector to increase its use of renewable energy by more than 300% in less than four years. During the period, technical assistance was provided to more than 160 energy projects that save nearly 500,000 kWh annually. Through its role in the Weatherization and Intergovernmental Program (WIP), NREL addressed significant barriers to the use of energy efficiency and renewable energy in international markets, at the state and local level, and by tribes.

New relationships were developed with industrial partners to transfer NREL knowledge and know-how, including three major CRADAs in bioenergy research with DuPont; BROIN and ABENGOA are still in negotiation. Increased industry participation in enterprise development programs and the outcomes resulting from these novel approaches to catalyze support for clean energy start-ups are evidence of their increased visibility and impact.

In addition, the Laboratory continued to work to enhance the effectiveness of its technology transfer processes by improvement of key processes, adding staff capabilities and training, and by acting on opportunities identified. Of particular note, NREL was presented a special award by the Federal Laboratory Consortium in recognition of the Laboratory's long-term efforts to facilitate the use of renewables to safeguard the nation's energy infrastructure.

Technology Transfer Highlights

Technical Assistance Enables Energy Projects

Through both FEMP and WIP, NREL served as a technical advisor and partner to other agencies in defining technical requirements of energy projects, evaluating options, and ensuring selected options meet their design specifications. Key highlights include:

- ***Technical Support to Projects Saves Energy and Reduces Costs.*** NREL far exceeded its project goal by supporting 163 federal EE/RE projects (goal was 80) this fiscal year. From these projects, $168M (goal was $50M) in new energy efficiency and renewable energy equipment was awarded to be installed at federal facilities through ESPC and UESC technical assistance. These projects result in 1,680,000 million BTUs or nearly 500,000 kWh saved annually at these sites. This equipment will save approximately $20.7M in taxpayer dollars annually.
- ***Onsite Renewable Projects Move Agencies Closer to Goal.*** NREL provided technical assistance to 43 onsite renewable projects (goal was 25) and nine renewable power procurement efforts. NREL's efforts supported FEMP in its goal to assist agencies in achieving the Executive Order goal of all agencies getting 2.5% of their electricity from a renewable source by the year 2005. At the end of FY03, the federal agencies were over 50% of this goal, compared to 14% two years ago and 26% onr year ago.
- ***International Project Assistance.*** NREL facilitated use of EERE technologies in several countries. For example, in Mexico, NREL developed a wind atlas for the state of Oaxaca showing 33,000MW of wind potential in the Isthmus region alone. Continued ESCO project facilitation has resulted in the first successful commercial financing of an ESCO

project in Mexico and a new ESCO partnership between a Mexican ESCO and Ameresco. In Brazil, NREL conducted evaluations & prepared technical reports for the Joanes and Campinas hybrid systems that have catalyzed local action to refurbish and replicate them.

- ***Tribal Energy Projects Supported.*** NREL provided technical assistance to the Sealaska and Bristol Bay tribes in Alaska, and to the Ramona and Manzanita tribes in California on anemometer siting and initial tribal capacity building regarding wind development. Biomass technical assistance was provided to the White Mountain Apache in Arizona, and the Choctaw in Mississippi.

Partnerships Enable Commercialization

Several significant partnerships were formed that will provide a key means of transferring knowledge and know-how. In addition, ongoing collaborations are leading to significant market impacts. Examples include:

- ***Natural Gas Engine Displaces 9.6 Million Gallons of Petroleum-Based Fuel.*** NREL collaborated with Cummins Westport, Inc. and other partners to develop the C-Gas Plus natural gas engine. In the first 20 months since production of the C-Gas Plus began, 1,044 engines were sold or ordered for use in transit buses in the United States. This represents approximately 9.6 million gallons of diesel fuel displacement annually, or 1.5% of the total U.S. annual diesel fuel consumption by transit buses. Vehicles equipped with the C-Gas Plus engine reduce some regulated emissions compared to conventional diesel counterparts.
- ***Three Major Biomass Program CRADAs Advanced.*** Several complex agreements were negotiated to allow NREL to work with three industrial partners awarded contracts under a DOE Office of Biomass Program solicitation. These agreements represent an overall DOE/NREL cost share of approximately $11.2M. DuPont de Nemours Company and NREL successfully negotiated a CRADA, FIA/WFO, and a license agreement. Abengoa Bioenergy Corporation and NREL are actively negotiating a CRADA along with the SOW. Additionally, Abengoa Bioenergy Corporation requested that critical terms of a license agreement be determined in parallel with entering into the CRADA. Broin & Associates and NREL have completed negotiation of a CRADA. Each of these partnerships is focused on critical aspects of a future biorefinery.
- ***Transfer of Diagnostic Tools Completed.*** GT Solar, Nashua, New Hampshire, licensed the NREL-developed *PV Reflectometer* technology and has initiated commercialization efforts. Due to its high-speed measurement capabilities, it is perfectly suited for the characterization of photovoltaic materials and finished solar cells in a production line environment.
- ***Partnerships Support Thin Film Commercialization.*** NREL's CRADA with Hewlett Packard was extended for an additional 12 months with $330K funds-in along with delivery of a $60K tool for reactive ion etching for use at NREL. This research will help to establish the infrastructure for thin-film manufacturing that can support both PV and micro-electronic applications. NREL also negotiated a CRADA with AKT, Inc. to adapt commercial thin-film production tools for PV processes. This partnership could provide predictable thin-film processes to U.S. businesses interested in PV.
- ***Collaborations Improve Battery Performance.*** NREL initiated collaboration with ElectraStor to improve their nickel hydrogen batteries. NREL evaluated, developed, and screened anodes and cathodes for this potentially high power, high-energy battery. This work supports the development and validation of batteries that can meet heavy hybrid vehicle technical targets. NREL used thermal characterization tools (calorimeter, infrared thermal imaging, and computer aided design) to provide technical support to Compact Power to improve thermal performance of lithium ion polymer gel batteries in three generations of cells. Improvements in third-generation cells have resulted in more uniform temperature distribution, lower maximum temperature, and less heat generation, all of which are needed for a more energy efficient and longer life battery operation.
- ***Wind Airfoil Licenses Respond to Market Pull for Replacement Blades.*** NREL negotiated licenses with two small businesses for the use of NREL's patented wind airfoil technology. These licenses help ensure a cost-competitive supply of blades to existing wind farms, and support small business success in renewable energy.
- ***WFO Project Shares Knowledge from Geothermal Program.*** NREL is funded via work for others to assess desalination of seawater using techniques developed for direct contact condensation within the Geothermal Technologies Program.

Enterprise Development

NREL continued to work to remove barriers to commercializing clean energy technologies via start-up companies. Key highlights include:

- ***Partnerships Established for 16th Industry Growth Forum.*** NREL received commitments for $125K in contributions for the upcoming 16th Industry Growth Forum, planned for November in Austin, Texas. The financial leverage attests to the value of this event significant to investors, clean energy companies, and interested stakeholders. NREL also instituted a new, Web-based process for clean energy company applications to the Forum, saving time for both applicants and reviewers. More than 100 companies have applied for the 35 presentation slots available.
- ***NREL Growth Link Expands Investment Networking with Clean Energy Companies.*** Growth Link is a web-based directory of clean energy companies seeking financing, partnering, and growth opportunities. Investors and energy firms can use the directory to find clean energy technologies that match their investment and strategic interests. Growth Link also provides a method for networking/connecting incubators, clean energy companies and investors, and gives each of these players additional exposure to the others. Participation is growing and has reached 150 companies.
- ***National Alliance of Clean Energy Business Incubators Exceeding Expectations.*** In the past two years, the organization has grown, attracting 10 of the nation's top incubators who are now committed to incubating and providing business services to clean energy entrepreneurs. Market performance and value of the Alliance is exceeding the expectations that were established at the beginning of the collaboration. Specific outcomes that have been achieved include:
  - Eighty companies are now in Alliance incubators
  - Approximately 1,000 jobs were created and supported by these companies
  - $5M in private capital was raised for the companies
  - $5M in state and local funds to the incubators significantly leverages the funds that were invested by DOE
  - Three companies have graduated from the incubators and are positioned for market success. NREL has successfully integrated the Alliance into other complimentary Enterprise Development activities to the mutual benefit of all partners.

Removing Information Barriers

NREL used a variety of mechanisms to transfer technical knowledge that enables consumers make informed energy choices. As examples:

- ***Vehicle and Fuel Information Provided to Stakeholders.*** NREL provided updates and additions to the information resources for Clean Cities coordinators, stakeholders, and fleet managers. New Web-based information in the Alternative Fuels Data Center on niche markets, fueling stations, funding resources, K-12 educational resources, and comparative fuel data addressed the most pressing needs for information identified in last year's Information Needs Assessment report. In addition, NREL completed total redesign of the Fleet Buyers Guide, an on-line tool that helps fleet managers identify applicable regulations and financial incentives, select appropriate vehicles and compare costs, find local fueling infrastructure, and access industry contacts and resources.
- ***Knowledge Transferred to Federal Energy Managers.*** NREL transferred its extensive knowledge and experience with technical solutions and best practices to federal energy managers and industry personnel to address their energy needs by presenting information to 3,100 people (goal was 2,000) through 81, technical workshops, and agency meetings. This far-reaching effort is indicative of the Laboratory's extensive knowledge and experience with the program; resulting in technical assistance with solutions and best practices that helps energy managers and industry personnel meet their energy needs.
- ***Labs for the 21st Century Gaining Momentum.*** NREL completed two case studies, five lab design courses, three best practice guides for laboratory design; design assistance on four new laboratory facilities, including NREL's Science and Technology Facility; a student design competition for a sustainable lab; and a parametric study of energy savings in four climate zones. These efforts contribute to the Labs for the 21st Century Program gaining momentum within the federal sector.
- ***Technical Assistance Provided to Clean Cities.*** NREL managed the delivery of Tiger Team technical assistance for several airport projects, a CNG fueling facility, and assisted coalitions with legislative, business development, and air pollution issues.
- ***Information Transferred to Educational Institutions.*** NREL published The Energy Smart Guide to Campus Cost Savings and distributed more than 800 copies of these guidelines to college and university officials. NREL delivered expert technical assistance for the design of the Baltimore Aquarium, and the Heritage Harbor Museum in Providence, Rhode Island.
- Renewable Energy Training Curriculum Prepared and Distributed. NREL developed a comprehensive training curriculum on renewable energy

technologies, applications, policies and programs for government officials and other stakeholders in developing countries. NREL worked with DOE, UNEP, AID, EPA, and others to disseminate and apply this curriculum in training around the world. NREL also provided weeklong training on Homer to 12 developing country partners.

- ***NREL and Regional Office Educate State Officials.*** NREL collaborated with DOE's Denver Regional Office and the National Conference of State Legislators in organizing and hosting a Renewable Energy Seminar for state legislators and state energy officials. More than 40 state officials from the Denver Region were exposed to a range of renewable energy technologies through informative presentations and hands-on demonstrations. Positive and effective results are already evident. Oklahoma organized a major wind power event attended by various state interests including regulators, legislators, developers, and manufacturers. The agenda included discussions on increasing the development of wind within the state, transmission, and Renewable Portfolio Standards (RPS).
- ***Expert Technical Assistance and Handbook for Tribal Energy Program.*** NREL prepared a draft Tribal Energy Guide to assist tribal officials in developing energy programs and policies and understanding the full potential for use of EERE technologies on tribal lands.

External Recognition

NREL expertise and leaderships in technology transfer was acknowledged by external awards, elections, and visibility.

- ***NREL Received Special Federal Laboratory Consortium (FLC) Award.*** The FLC Mid-Continent region recently honored NREL with an award for Outstanding Technology Development in recognition of the Laboratory's long-term efforts for "*Using Renewables to Safeguard the Energy Infrastructure of the U.S.*" This award recognizes the outstanding work of all Laboratory staff and enhances NREL's visibility within the FLC.
- ***Technology Transfer Office Director elected to DOE Technology Partnerships Working Group (TPWG) Executive Committee.*** The Executive Committee serves as the liaison and point of contact for communications among representatives from DOE-HQ, DOE field offices, and DOE facilities on technology partnership topics. The position will allow NREL to exert more leadership toward increasing the effectiveness of technology transfer in the DOE system.
- ***NREL Technology Commercialization Report Deemed Valuable.*** NREL's report entitled "Bridging the Valley of Death: Transitioning from Public Sector to Private Sector Financing," was coauthored by a member of the venture capital industry. The DOE TPWG found the report so insightful that it was distributed to all DOE laboratories, and a presentation of the findings placed on the agenda for the annual TPWG meeting. The report will lead to enhanced credibility for NREL and increased understanding of the importance of financing issues and their resolution.

Technology Transfer Process Enhancements

NREL maintained its commitment to continuous improvement through process enhancements and development of tools that enable technology transfer.

- ***Intellectual Property Framework Developed for Multi-Participant Virtual Center.*** As part of a response to a DOE competitive solicitation, NREL developed an intellectual property plan and negotiated its approval with the seven universities, three federal laboratories, and a private sector entity that are part of the virtual center team. This model will facilitate the development of other virtual centers in the future.
- ***NREL Develops Process for Qualifying Potential Licensees.*** Negotiating licenses with partners who are not well-qualified to commercialize the technology can waste significant amounts of time, and potentially result in good technology that is tied up with an ineffective partner. NREL has developed a new process for completing due diligence on all partners that are interested in a licensing agreement. The approach has led to reduced execution time for two licenses, and resulted in quick termination of discussions with three interested parties.
- ***NREL Develops Two Technology Transfer Databases.*** The Negotiations Status Report (NSR) database tracks all ongoing license negotiations at the Laboratory, resulting in better coordination of limited resources and faster execution of licenses. Another database tracks our licensing accomplishments using guidelines developed by DOE for technology partnership programs, and ensures we can rapidly comply with DOE requests for information.
- ***License Administration Process Gets Results.*** The overhaul that NREL made to its process for administering existing license agreements continued to yield results. We have moved from a licensee compliance rate of less than 75% to 94% today. The single license that is not in compliance has an action plan aimed at bringing it into compliance.

- ***Critical Training in Intellectual Property Management Elements Provided.*** A training and orientation session on patent management software (PATTSY) was provided for Laboratory intellectual property/technology transfer staff members, who need to manage dates for filings and payments to assure integrity of intellectual property process. The Patent Counsel provided training on the legal aspects of the inventor's role to the National Bioenergy Center staff. In addition, a briefing to NREL senior management was provided on the legal sufficiency of electronic laboratory notebooks for protecting Laboratory intellectual property. The briefing was responsive to the issuance of the DOE draft guideline pertaining to the possible future use of electronic notebooks within the DOE laboratory complex**.**

- ***Standardized Metrics for Transferring NREL Technology.*** The Laboratory monitors several "standard" technology transfer metrics over time to gain a balanced perspective on the activity level and associated benefits. Regular evaluation has resulted in a number of enhancements over time including those discussed in the table below, and in previous reports..

Standardized Metrics for Transferring NREL Technology

	FY01 Total	**FY02 Total**	**FY03 Total**
Publications	910	1048	1116
Record of Inventions	52	35	34
Patent Applications (includes U.S., Foreign, PCTs)	68	81	49(1)
Licenses	2	6	6
Active Licenses	30	25	26
FIA/WFO	23	29	28
New CRADAs	10	11	7
$TPA	$10,541,390	$9,488,869	$9,007,000

(1) The decline in patent applications for FY03 is related to the decline of Records of Invention between FY01 and FY02.